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Short breaks at school: effects of a physical activity and a mindfulness intervention on children's attention, reading comprehension, and self-esteem

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ABSTRACT

Background: Although breaks are essential to restoring cognitive and psychological conditions for learning, short breaks within school lessons are not established and the specificity of effects has not often been investigated. Therefore, the effects of a physical activity (Study 1) and a mindfulness intervention (Study 2) were investigated.
Procedure: By an intervention-control group design, the effects of daily 10-min physical activity (Study 1: N = 162, 4th grade) and mindfulness breaks (Study 2: N = 79, 5th grade) were implemented within regular school lessons over a 2-week time period to research the impact on attention, reading comprehension, and self-esteem.
Results: In the physical activity intervention children's attention improved (attention-processing speed: $p < .004$, $\eta_p^2 = .05$, attention-performance: $p < .025$, $\eta_p^2 = .03$), and in the mindfulness intervention reading comprehension improved ($p < .012$, $\eta_p^2 = .08$) compared to the controls. Results further indicated that self-esteem moderated the relationship between groups and attention improvement in study 1.
Conclusion: Classroom-based short physical and mindfulness breaks could support attention and reading comprehension, which are known to support overall academic success.

Attention and the ability to focus without distraction is essential for learning and academic success [1–6], but attention is a limited resource and is constantly shifting [7,8]. Especially school children's attention is challenged and influenced by many internal and external factors such as school-related stress [9], being bored [10], or disproportionate sedentary behavior [11–14]. Inattention alters information-processing responses from a task-directed mode to a sensory-vigilance mode causing cognitive costs and reducing the processing of incoming information and therefore impairing learning [15,16]. One way to restore attention are breaks [17,18], specifically physical activity [19] and mindfulness interventions [20]. However, study results are heterogeneous and interventions have not often been implemented within classroom settings.

The growing body of research reported overall positive effects of physical activities on attention and academic achievements [21–23] but also reported differentiated results and that physical activity had limited or no effect on cognition or on academic achievements [24]. In this context, the role of moderators is discussed. One meta-analysis investigating the effects of physical activities on children's attention, executive functions, and academic performance found that physical activity effects depended on the type of intervention and cognitive domain [25]. However, another meta-analysis investigating the effects of physical activity on children's cognition, academic achievements and verbal skills found that effects were not moderated by the type of physical activity [26]. Mixed results were also reported for studies comparing acute (single session) and chronic effects of physical activity on cognition. In one meta-analysis, comparing acute (17 studies) and chronic (14 studies) physical activities, acute physical activity affected children's (6-12 years) attentional measures but not executive functions, whereas

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chronic interventions affected all cognitive domains [25]. In contrast to this, one meta-analysis also comparing acute (14 studies) and chronic physical activities (22 studies) reported positive effects on children's and adolescents' (5-18 years) executive functions after acute as well as chronic physical activity interventions [27].

An additional debate in this field is whether physical activities were more effective if they were cognitively engaging [28,29]. In one meta-analysis, the effects of cognitively engaging exercises were stronger than of conventional physical activity such as aerobic activities or motor skill training [30]. The results were, however, based on only two studies, and the cognitive engaged physical intervention were yoga meditation and breathing exercises, which might refer more to mindfulness, and intervention were daily programs of a summer camp and not standardized (8h/day for 10 days or 75 min/day for 7 days, respectively). Another meta-analysis including 36 studies (with 16 studies categorized as enriching and increasing cognitive demands) reported however, positive effects after cognitive engaging exercises (e. g. dancing, body-bilateral combination exercises) on selective attention, inhibition but not on working memory and higher-level executive functions [31].

The inconsistent results refer to heterogeneity between studies. A recent review of 19 reviews and meta-analyses on the effects of physical activity on children's cognition and academic achievement concluded that studies often were low quality and did not have controlled baselines, lacked validated outcome measures, lacked detailed reporting or had low standardization [32]. The lack of studies with higher quality was also reported in a review by an expert panel on chronic effects of physical activity [33] as well as in one review on acute effects of physical activity on children's cognition [34].

A similar pattern occurs for physical activity effects on children's academic performance. One recent meta-analysis including 44 studies reported mixed results of physical activity (i. e. extracurricular physical activity longer than six weeks) on children's (5-16 years) academic performances (e. g. grades, standardized tests) but also reported high heterogeneity between studies [35]. In the context of academic outcomes, few studies investigated the effects of physical activity on reading comprehension although reading comprehension is key to overall academic success [36]. One meta-analysis of 59 studies, which evaluated the impact of physical activities on academic performance in children (6-16 years) reported the highest effects on math and reading performance [37]. Yet, a similar meta-analysis of 31 studies with children (6-12 years) found no effects for physical activity on math nor reading [25]. Heterogeneous results might be due the different publication periods of included studies (Fedewa: 1947-2009; Greef: 2000-2017), lack of studies (e. g. Greef: only 3 studies had reading outcomes), and different age ranges of samples (Fedewa: 6-16; Greef: 6-12).

For classroom based physical interventions, the effects on cognition outcomes are similar inconclusive. One meta-analysis, including 11 classroom-based physical activity interventions effects on children's attention, concluded that no clear positive effects of physical activity breaks on children's attention occurred, and that heterogeneity between studies was high [38]. Authors also referred to that only a small number of classroom-based studies existed and that one key factor could be the person applying the physical activity who motivated students and performed physical activities as a role model.

Another intervention used to restore attention and cognition capacities are mindfulness interventions. Mindfulness is defined as "paying attention in a particular way: on purpose, in the present moment, and non-judgmentally" [39]. Mindfulness based stress reduction (MBSR) interventions traditionally focus on psychological health and well-being [40–43].

More and more mindfulness studies have been investigating effects of mindfulness in nonclinical settings and on attention and information processing [44]. One meta-analysis on the efficacy of randomized controlled trials in children and adolescents (younger than 18) reported positive effects of mindfulness on executive functions, attention, as well as on mental health [45]. A similar pattern of results emerged for effects on executive attention in a meta-analysis of mindfulness interventions at school [46]. The overall effect size on cognitive performance in this meta-analysis was large (Hedge's $g = 0.80$) but the diversity between studies interventions, exercises, and measures were large, as well.

Despite the growing body of mindfulness studies with positive effects on attention and executive functions, which are connected to academic performance [47], only few mindfulness studies focused on specific academic performance [46,48]. Some mindfulness interventions in elementary and middle school have led to improvements in standardized tests scores in math and English language [49] or improved results of the General Certificate of Education Exam (i. e. national standard academic test [50]). However, samples in these studies were children at risk (97% minorities) or small (n-intervention = 11, n-control = 13). One study with Spanish students from ninth grade ($N = 61$) reported improvements of school grades (philosophy, Spanish language, literature, foreign language) after a mindfulness intervention (10 × 90-min sessions) [51]. Another study with younger children from fourth and fifth grade ($N = 99$) reported, however, no significant improvement for math grades, but a trend toward higher grades after mindfulness intervention (52). Only few mindfulness studies investigated mindfulness effects on reading. One mindfulness study with undergraduate students, improved reading comprehension compared to controls after a relative high intensity intervention with 4 weekly 45-min sessions over 2 weeks [53]. Another study with undergraduate students, also reported improved reading comprehension after a single 15-min mindfulness intervention compared to controls [54]. One study including pre-kindergarten children who attended 15 mindfulness-based lessons (20-30 min each) in combination with additionally daily brief mindfulness practice (30-60 s) over the course of the school year also reported improved vocabulary and reading abilities compared to a control group [55]. However, the mindfulness-based lessons in this study were conducted by teachers and were not standardized. In another study, elementary school children ($N = 93$) listened daily to 10-min mindfulness audios within regular school lessons over 8 weeks and being in the mindfulness intervention displayed significantly post-intervention reading grades (as opposed to the control) [56]. However, measures were not standardized and grades between children in intervention and control groups differed at pretest. Heterogeneous results might be due heterogeneous methodological quality of mindfulness studies. Mindfulness intervention studies are trending and publications are increasing vastly [57], but are criticized due to small samples, missing control groups, heterogeneous measures, and lacking information on mindfulness intervention content and standardizing [58,59].

Apart from attention and reading, another necessity for learning and academic success at school is self-esteem [60]. Although self-esteem is the 'global perception of the self as a person' [61] studies reported that students with higher self-esteem performed better in academic settings compared to students with lower self-esteem [62]. Results on the relationship between self-esteem and academic achievement in reviews are inconsistent and referred to be either reciprocal [63] or independent [64]. Alternatively, it was assumed that self-esteem could play a moderating role between attention and academic performance [65]. Due to the promising associations between self-esteem and academic achievement (as well as for its mental health relevance), self-esteem has also been impacted by physical activity and mindfulness interventions. Physical activity influenced self-esteem overall positively [66], but results were inclusive and effects depended on the kind of physical activity, population, or gender [67]. Similar overall positive effects on self-esteem were reported after mindfulness interventions, but results should be interpreted with caution due to methodological weaknesses of mindfulness studies [68].

Current physical activities and mindfulness interventions with children are seldom classroom-based, which can be contributed to the competing demand for time at school and maximizing time for academic outcome [31,69].

However, data suggested that short breaks would not interfere effective learning or time on task, but would support learning processes and classroom behaviour [70,71]. Shorter lesson units (i. e. more breaks) kept attention of students at school higher, particularly of younger ones [72]. Additionally, classroom-based interventions would provide higher ecological validity than experimental settings, as classroom's complex influencing environments [73], peer relations [74–76], student-teacher relationships [77], and school-related stress [78] were included. Some classroom-based physical activity and mindfulness interventions to recover attention and mood have been implemented within lessons in institutional settings and revealed overall positive effects [69,79].

In summary, previous physical activity and mindfulness interventions indicated heterogeneous results on cognitive (attention, reading comprehension) and social (self-esteem) learning conditions and have seldom been implemented in classrooms, and have not been investigated together within similar conditions.

Therefore, the present study investigated the effects of a physical activity (study 1) and a mindfulness intervention (study 2) on attention, reading comprehension and self-esteem in two controlled trials. Based on previous findings, we expected positive effects of physical exercise and mindfulness intervention on attention and reading comprehension compared to controls and moderating effects for self-esteem.

1. Method

1.1. Participants

Using G*Power [80] and a-priori power analysis with the parameters alpha = .05, power = 0.95, η_p^2 = .05, indicated that a sample size of N = 64 was necessary in order to test the effects of interest.

In study 1 (physical activity), 162 students from 4th grade of two state elementary schools in Frankfurt/Main, Germany participated (female = 54.9 %; Mage = 121.56 months; n-intervention = 93 (4 classes), n-control = 69 (4 classes)). In study 2 (mindfulness training), 79 students from 5th grade of one state school (*Gesamtschule*, comprehensive school) in Frankfurt/Main, Germany participated (female = 48.1%; Mage = 136.68 months; n-intervention = 42 (2 classes), n-control = 37 (2 classes)). Children were randomly assigned based on class level to either an intervention or a control group. Parents were informed about the study by letter, which included a parental consent form, which needed to be signed in order to include the child in the study. The participation was voluntary, neither the students nor their parents received any incentives.

1.2. Procedure

For both studies, an intervention-control group design based on class level was applied (see Fig. 1). Intervention duration in both studies were 2 weeks with daily 10-min short breaks in children's classrooms. All short breaks (intervention and control sessions) started at least after 90-min of regular school lessons, before 12 a.m., and sessions were not implemented after regular breaks or after PE lessons.

Both studies followed same regimen for pretests, posttests, and interventions. Pre- and posttest were instructed and supervised by two research assistants of the university in the children's classrooms. Pretests were conducted on a Thursday or Friday prior to the first week of intervention. The data assessment of the posttests took place directly after the last session. Attention, reading comprehension, and self-esteem were measured on the pre- as well as posttest. Additional measures, which are not reported here but were part of another research project, were body image [81] and attribution [82]. Through the pretest, additional data on demographics (age, gender) and intelligence were assessed. With the posttest of study 2, additional data on motivation and evaluation of interventions were assessed. All intervention sessions (physical activity, mindfulness) were implemented and executed by research assistants of the university in the children's classroom during regular school lessons. Research assistants were randomly assigned to classes daily. Prior to the interventions at schools, research assistants attended workshops conducted by a professional sports coach or experienced mindfulness trainer, respectively, in order to learn about instruction and standardizing of intervention sessions.

Study 1 (physical activity) The physical activity intervention was developed in cooperation with sport scientists and was based on meta-analytic evidence on duration and intensity [69], standardization by live coaches (e. g. [38]), as well as safety concerns for in-class activity and to be adequate for children [83]. Each session lasted 10-min consisting of four phases: a 2-min warming-up (shoulders: rotation circles, body: arm stretch with a twist, neck: moving head slowly left and right), 4-min interval-based medium cardiovascular activities (8 times 20-s interval-based exercises with ca. 10-s rest between exercises; following order of exercises: running in place, jumping jacks, cross elbow to knee touch, invisible jump rope, cross heel touch, high knees, windmill and foot fire), 2-min exercises with a partner (back to back knee bend), and 2-min cool down with balance tasks (standing scale and tree pose) and stretching. Interventions were instructed and performed in children's classrooms by live trainers of the university serving as role models. For additional standardization, an audio file with timing of exercises and with typical workout background music was recorded and played during all interventions.

Study 2 (mindfulness training) The mindfulness intervention was developed by experienced mindfulness practitioners while considering guidelines for mindfulness interventions with children [84]. Prior to the mindfulness interventions a short 2-min psychoeducational input was implemented, followed by 10-min of classic mindfulness exercises. During the psychoeducational input, children were introduced to mindfulness (e. g., finding the right position on a chair, relaxing the mind, wandering of thoughts). During each input supporting pictures were presented (e. g. clouds in the sky, a tree in different seasons). The subsequent mindfulness interventions included breathing exercises, guided attention exercises (e. g. What do you hear in the background?, How do you feel right now?), and a body scan. For standardization, an audio file for the mindfulness instructions and timed intervals was recorded and played during all classroom-based mindfulness interventions. Research assistants presented the psychoeducational input and participated in the mindfulness intervention with children serving as a role model.

Control groups In study 1 and 2, children of the control groups also

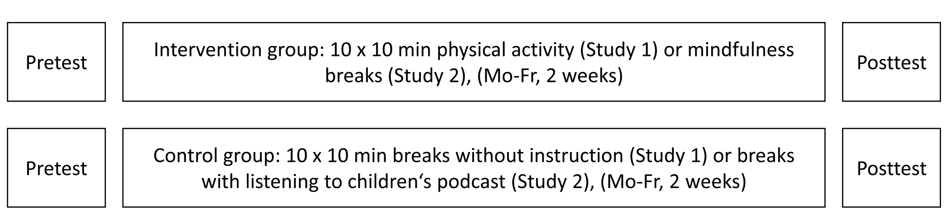

Fig 1. Pre-post intervention-control group study design for study 1 (physical activity) and 2 (mindfulness).

had additional breaks within school lessons. In study 1, children of the control group had breaks without further instructions (i. e. children were allowed within school regulations to have conversations, stand up, walk around in the classroom, eat, drink, but not using mobile phones or running around). In study 2, children of the control group listened to a children's podcast during breaks. The children's podcast addressed family, its members, their hobbies, and family activities. The family story was developed by experienced teachers and used the same visual stimuli as in the mindfulness psychoeducational input of the mindfulness intervention.

1.3. Measures

Attention Children's attention was assessed by the d2-R test [85]. Test items consist of the letters d and p with one to four dashes arranged either individually or in pairs above or below the letter. Frequency of letters was balanced and printed on one page with 14 lines and 57 letters for each line. Participants had to mark only d letters with two dashes above or below or with one dash above and below. Test was timed and was 4 min 40 s (20-s per line). The d2-R allows calculation of three attention measures: i) attention-processing speed (total number of correctly crossed letters), ii) rule-compliance (percentage of errors relative to processing speed), and iii) attention-performance (total number of errors subtracted from the total number of correctly crossed d letters). While attention-processing speed is considered a quantitative measure of the attentional speed, rule-compliance is a measure of precision and thoroughness. Attention-performance is reflecting individual attention span and concentration ability [86]. Internal consistency (Cronbach's alpha) of the d2-R is high according to manual (attention-processing speed: .96, attention-performance: .96, rule-compliance: .87). For analyses, raw scores were used.

Reading comprehension To assess reading comprehension, the subscale "text comprehension" (20 items) of the ELFE 1-6 [87] was used. For each item, children read one sentence or more sentences (with increasing complexity) and chose one from four given sentences matching the given content. The test was timed and stopped after 10 minutes. Internal consistency (Cronbach's alpha) for 'text comprehension' is high (.92) according to manual. For analyses, raw scores were used (range 0-20).

Self-esteem For self-esteem the Rosenberg self-esteem scale (RSE) was used [88]. The 10-item scale relates to overall feelings of self-worth or self-acceptance (e. g., 'Overall, I am satisfied with myself'). Items are rated on a 5-point-Likert scale (1 = strongly disagree to 5 = strongly agree). Internal consistency (Cronbach's alpha) for this subscale is acceptable (.65) according to manual. For analysis, participants' mean total score were used (range 1-5).

Intelligence Children's intelligence was assessed by one subscale (i. e. part 1, test 3; 15 items) of the Culture Fair Intelligence Test (CFT 20-R [89]). Items are matrices displaying geometrical figures with one empty fields. Participants chose one from five alternatives, for the empty field. Test for intelligence was timed 3 min. Internal consistency (Mosier's) for this subscale is high (.86-.96) according to manual. For analysis participants mean raw score was used (range was 0-15).

Clinical screening For clinical screening and positive attributes the German version of the Strengths and Difficulties Questionnaire (SDQ) was used [90]. The SDQ consists of 25 items which are assessed by a 3-point Likert scale (0 = not true, 1 = partly true, 2 = true). Items are allocated to five subscales: 'emotional problems' (e. g., 'I worry a lot'), 'conduct problems' (e. g., 'I often get very angry and lose my temper'), 'hyperactivity/inattention' (e. g., 'I am easily distracted', 'I find it difficult to concentrate'), 'problems with peers' (e. g., 'Other people my age generally like me'), and 'prosocial behavior' (e. g., 'I usually share things with others, for example CDs, games, food'). Internal consistency (Cronbach's alpha) has been reported to be acceptable or good in the manual (between .56-.76). According to manual the 'normal' range (i. e. not clinical or abnormal behavior) for 'emotional problems' is 0-5, for 'conduct problems' is 0-3, for 'hyperactivity' is 0-5, and for 'problems with peers' is 0-3. For the 'prosocial behavior', it is inverse and the normal range is 6-10 and scores less than 6 are referred to borderline or abnormal behavior.

Demographics, motivation, evaluation of short breaks Through pretest, participants provided personal information regarding age and gender. In study 2 and before posttest, participants answered additional items for motivation ('During breaks I was motivated') and evaluation of breaks ('The additional breaks were useful') on a 5-point scale ranging from 1 for "not at all" to 5 for "very much".

1.4. Data Analysis

We adopted a 2 (pretest, posttest) x 2 (intervention group, control group) design for both studies. Only children who attended at least eight of ten intervention sessions and who took part at pre- and posttest assessments were included in the study. Missing data was 3.01% and Little's MCAR test [91] suggested it was missing completely at random ($\chi^2(99) = 81.10$, $p = .905$). Thus, to reduce potential bias from listwise deletion, multiple imputation in SPSS were performed, using five imputations. Results reflected pooled estimates across imputations [92, 93]. Before main analysis, baseline differences were tested by one-way ANOVA to compare age, intelligence, clinical symptoms, and all dependent variables between groups. Moreover, a Chi-Square test was utilized to compare gender distribution between groups for each study. To test for intervention-related changes, we ran variance analyses with repeated measures (ANOVAs) indicating time (pretest, posttest) as within-subjects factor, and group (intervention, control) as between subject factor for all dependent variables. For significant interactions, post hoc paired *t*-tests were calculated. All analyses were performed using SPSS version 27. Results were considered significant at $p < .05$. Moderation analysis was carried out for significant interactions to examine whether the relationship between group (intervention, control) and outcome variable were moderated by self-esteem score at pretest. Moderation were performed using criteria suggested by Baron [94] and for the criterion, difference scores (posttest - pretest) were used [95]. We followed procedure by using the macro PROCESS for SPSS (96). The presence of a significant moderation effect was denoted if zero was not included by the upper and lower bound of 95% CI and by test of significance of the interaction. In order to probe a significant interaction we report the conditional effect of groups on difference score and self-esteem at low (-1 *SD*), average, and high ($+1$ *SD*) level [97]. We also report the value of the moderator at which the predictor no longer has a significant relationship with the criterion by Johnson-Neyman technique [98].

2. Results

2.1. Controlling for pretest differences

Results for gender, age, intelligence, clinical screening (Table 1), and dependent variables at pretest (Table 2) revealed that participants of intervention and control groups of study 1 and 2 did not differ (all *p*-values $> .05$) and participants showed no clinical symptoms. In study 2 and SDQ-subscale 'problems with peers' the intervention and control group were slightly above 'normal'.

In Table 2 means, standard deviations at pre- and post-test scores for attention scales, reading comprehension, and self-esteem are reported.

2.2. Intervention effects

In Table 3 repeated measures ANOVA results are presented. In study 1 main effects of time for all measures except self-esteem were found and in study 2 similar main effects except for reading comprehension were found. In both studies, no significant main effects of group were found. Importantly, in study 1 significant interaction effects for attention

Table 1
Age, gender, intelligence, clinical screening of participants at pretest.

Study 1	Physical activity ($n = 93$)	Control ($n = 69$)	Group difference at pretest
Gender: male (m), female (f)	m: 39, f: 54	m: 34, f: 35	$\chi 2 = .862, p = .353$
Age (months), (Mean, *SD*)	121.24 (7.64)	122.00 (7.72)	$F = 0.392, p = .532$
CFT 20-R (Mean, *SD*)	8.68 (2.33)	8.51 (2.44)	$F = 0.191, p = .663$
SDQ-emotional problems (Mean, *SD*)	3.18 (2.40)	3.61 (2.32)	$F = 1.319, p = .252$
SDQ-conduct problems (Mean, *SD*)	2.51 (1.81)	2.55 (1.58)	$F = 0.027, p = .871$
SDP-hyperactivity (Mean, *SD*)	3.57 (2.28)	3.66 (2.18)	$F = 0.050, p = .824$
SDQ-problems with peers (Mean, *SD*)	2.89 (1.93)	2.88 (1.70)	$F = 0.002, p = .967$
SDQ-prosocial behavior (Mean, *SD*)	7.22 (2.09)	7.72 (1.79)	$F = 2.569, p = .111$
Study 2	**Mindfulness ($n = 42$)**	**Control ($n = 37$)**	**Group difference at pretest**
Gender: male (m), female (f)	m: 22, f: 20	m: 19, f: 18	$\chi 2 = .008, p = .927$
Age (months), (Mean, *SD*)	137.83 (6.23)	135.41 (6.00)	$F = 3.091, p = .083$
CFT 20-R (Mean, *SD*)	7.83 (2.53)	8.35 (2.36)	$F = 0.875, p = .352$
SDQ-emotional problems (Mean, *SD*)	3.42 (2.56)	4.21 (2.26)	$F = 2.079, p = .153$
SDQ-conduct problems (Mean, *SD*)	2.57 (1.90)	3.27 (1.95)	$F = 2.614, p = .110$
SDP-hyperactivity (Mean, *SD*)	4.13 (2.22)	4.68 (2.26)	$F = 1.178, p = .281$
SDQ-problems with peers (Mean, *SD*)	3.43 (1.56)	3.59 (1.91)	$F = 0.172, p = .679$
SDQ-prosocial behavior (Mean, *SD*)	7.20 (1.85)	7.95 (1.63)	$F = 3.583, p = .062$

Note. CFT 20-R = cognitive abilities; SDQ-emotional problems: 0-5 = normal; SDQ-conduct problems: 0-3 = normal; SDQ-hyperactivity: 0-5 = normal; SDQ-problems with peers: 0-3 = normal; SDQ-prosocial behavior: 6-10 = normal.

processing speed ($F(1, 160) = 8.358, p = < .004, \eta_p^2 = .05$), and attention performance ($F(1, 160) = 5.091$, $p = .025$, $\eta_p^2 = .031$) were found (Fig. 2). Post hoc comparisons revealed that both groups increased from pre- to posttest (all *p*-values < . 001), but impacts were more pronounced in the intervention than in the control group. No interaction effects were found for reading comprehension and self-esteem in study 1.

In study 2, a significant interaction was found for reading comprehension ($F(1, 77) = 4.96$, $p = .012$, $\eta_p^2 = .079$) (Fig. 2). Post hoc comparisons revealed that reading score improved significantly in the intervention ($p = .004$), but not in the control group ($p = .452$). No significant interactions for attention scores and self-esteem were found in study 2. For additional between-subjects factors (motivation during breaks and evaluation of breaks) no significant interaction for all dependent variables was found ($p > .05$, respectively).

2.3. Moderation effects

For the significant interaction on attention-performance in study 1, we tested whether self-esteem moderated the relationship between group (intervention, control) and gain of attention-performance (gain = posttest – pretest) (Fig. 3).

Self-esteem scores on the pretest met conditions for moderators by Baron [94] and was uncorrelated with the predictor and criterion. The overall model was significant ($R^2 = 7.01$ %, $F(3, 158) = 3.968$, $p = .009$). Results show that self-esteem moderated the effect between group (intervention group coded as 0, control group coded as 1) and attention performance gain significantly ($\Delta R^2 = 3.01\%$, $F(1, 158) = 5.114$, $p = .025$, 95% CI[0.395, 5.846]). In order to probe this conditional association, we tested the significance of the simple slopes at different levels of self-esteem (-1 *SD*, average, and +1 *SD*). Tests showed that there was a significant relationship between group and the attention gain when self-esteem was “low” ($b = -4.0892$, 95% CI[-6.6024, -1.5760], $t(158) = -3.2137$, $p = .0016$) or “medium” ($b = -2.0523$, 95% CI[-3.8299, -0.2748], $t(158) = -2.2804$, $p = .0239$) but not when self-esteem was “high” (Fig. 4). The Johnson-Neyman technique indicated that group was no longer related to attention gain when self-esteem was at 3.69 (on a 1-5 scale) or greater ($b = -1.7923$, 95% CI[3.5846, .00], $t(158) = -1.9751$, $p = .05$).

In study 1 no corresponding moderating effects on attention-processing speed was found and in study 2 (mindfulness) no moderating effect of self-esteem on reading comprehension gain was found.

3. Discussion

In this study, the effects of a classroom-based physical activity and a mindfulness intervention on children’s attention, reading comprehension, and self-esteem were investigated. Physical activities improved children’s attention while the mindfulness intervention improved reading comprehension compared to the controls. Results further indicated that self-esteem moderated the relationship between groups and improvement of attention in the physical activity intervention. Results in study 1, and positive effects after the physical activity on attention, are in line with overall positive effects of physical activities on cognition [25,99] and with classroom-based physical activity interventions with

Table 2
Pre- and posttest of outcome variables of study 1 (physical activity) and 2 (mindfulness).

Study 1	Physical activity ($n = 93$)				Control ($n = 69$)				Group difference at pretest
	Pre M	(SD)	Post M	(SD)	Pre M	(SD)	Post M	(SD)	One-way ANOVA
d2-R processing speed	101.59	(14.89)	124.09	(17.41)	105.87	(18.58)	123.29	(22.52)	$F = 2.645, p = .106$
d2-R rule compliance %	6.21	(5.71)	3.40	(3.36)	7.73	(6.68)	3.90	(4.68)	$F = 2.413, p = .122$
d2-R performance	95.26	(15.04)	119.87	(17.28)	97.78	(18.85)	118.28	(21.17)	$F = 0.898, p = .345$
ELFE-reading	12.39	(4.22)	13.90	(3.98)	13.35	(4.22)	14.68	(4.28)	$F = 2.029, p = .156$
Self-esteem	3.62	(0.65)	3.55	(0.67)	3.61	(0.67)	3.60	(0.72)	$F = 0.003, p = .954$
Study 2	**Mindfulness ($n = 42$)**				**Control ($n = 37$)**				**Group difference at pretest**
	Pre M	(SD)	Post M	(SD)	Pre M	(SD)	Post M	(SD)	One-way ANOVA
d2-R processing speed	127.29	(24.78)	142.07	(31.43)	121.60	(22.21)	138.54	(26.16)	$F = 1.143, p = .288$
d2-R rule compliance %	11.88	(12.10)	9.75	(12.76)	10.57	(11.16)	8.79	(8.21)	$F = 0.246, p = .621$
d2-R performance	110.43	(17.86)	126.48	(26.67)	108.22	(21.89)	126.54	(26.12)	$F = 0.245, p = .622$
ELFE-reading	13.64	(3.63)	15.02	(3.61)	13.78	(3.99)	13.40	(4.41)	$F = 0.027, p = .870$
Self-esteem	3.41	(0.57)	3.58	(0.56)	3.35	(0.63)	3.39	(0.71)	$F = 0.233, p = .631$

Note. d2-R processing-speed = total number of responses; d2-R rule-compliance = ratio errors to the total number of responses; d2-R performance = number of correct responses minus errors; ELFE-reading = reading comprehension.

Table 3
ANOVA results and effect sizes of study 1 (physical activity) and study 2 (mindfulness).

	Time				Group				Time x Group			
	F	*df*	*p*	*d*	*F*	*df*	*p*	*d*	*F*	*df*	*p*	η_p^2
Study 1 (Physical activity)												
d2-R processing speed	517.175	160	.000	3.599	0.398	1	.529	0.090	8.358	160	.004	.050
d2-R rule compliance %	62.042	160	.000	1.244	2.03	1	.157	0.220	1.479	160	.226	.009
d2-R performance	610.201	160	.000	3.903	0.030	1	.864	0	5.091	160	.025	.031
ELFE reading	54.963	160	.000	1.173	1.873	1	.173	0.220	0.213	160	.645	.001
Self-esteem	0.960	160	.329	0.155	0.054	1	.816	0	0.569	160	.452	.004
Study 2 (Mindfulness)												
d2-R processing speed	40.679	77	.000	1.454	0.721	1	.398	0.191	0.189	77	.665	.002
d2-R rule compliance %	5.499	77	.022	0.536	0.222	1	.639	0.110	0.043	77	.835	.001
d2-R performance	104.439	77	.000	2.331	0.046	1	.830	0.063	0.458	77	.500	.006
ELFE reading	2.130	77	.148	0.333	0.831	1	.365	0.211	6.561	77	.012	.079
Self-esteem	3.076	77	.083	0.398	0.979	1	.326	0.230	1.049	77	.309	.013

Note. d2-R processing speed = total number of responses; d2-R rule compliance = number of errors related to the total number of responses; d2-R performance = number of correct responses minus errors of confusion; *d* = Cohen's d.

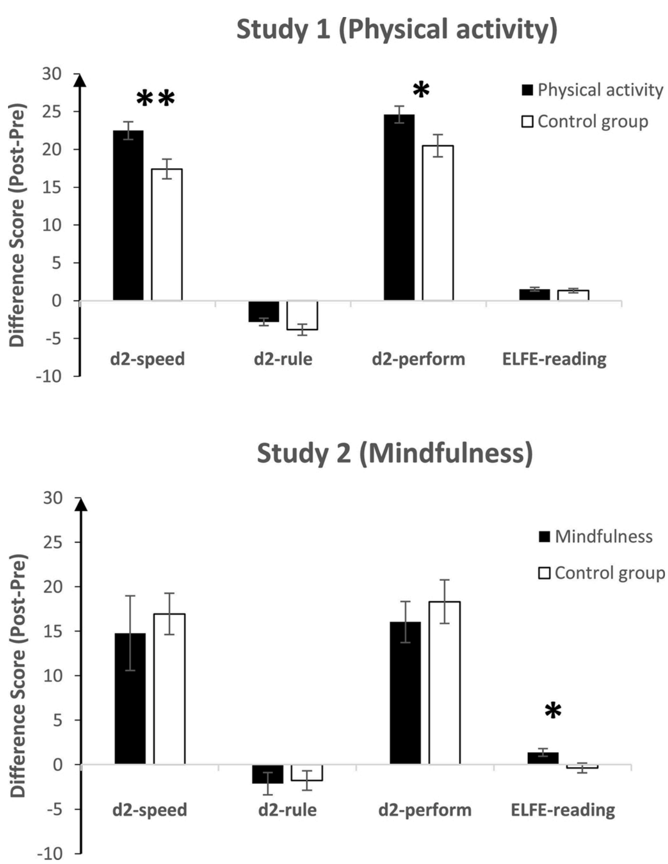

Fig 2. Difference scores (posttest-pretest, ± standard error of the mean) of study 1 (Physical activity) and study 2 (Mindfulness); d2-speed = total number of responses, d2-rule = ratio errors to the total number of responses, d2-perfom = number of correct responses minus errors; **p < .01, *p < .05.

different samples and different physical intervention intensity [100]. Generalization of results are however limited due heterogeneous methodology between studies. For example, one physical activity study [29], with elementary school children using the same measure for attention (d2-R), reported no intervention effects after five 10-min sessions over 3 weeks of classroom-based physical activity compared to two different cognitive engaging intervention groups and a passive control group. According to authors, breaks were only effective if cognitively engaging, and assumed a curvilinear relationship between physical activity duration and attention and concluded that effective breaks needed to be more than 10-min. Yet, the non-significant effects could also be contributed to the '10-min of running at different speeds' intervention which possibly needed more variation or might not have been ideal for classrooms.

In study 1 (physical activity), only attention's processing speed and attention performance improved more than in the control group, but not attention's rule compliance. This points to a quantitative (indicated by increased speed) rather than a qualitative (indicated by higher accuracy) improvement. There is previous evidence indicating that physical activity improved speed but not accuracy in attention tests [29,101]. Yet, Budde [86] found both improved attentional speed and accuracy after physical exercise (using the same measure for attention as in our study). However, this study examined acute effects and included elite students who practiced sport every day (25-30 h per week) and findings may not be indicative of our study population.

After the mindfulness intervention no effects on attention subscales were revealed, which adds to the heterogeneous results of mindfulness on cognition and attention but needed further evidence as classroom-based mindfulness interventions on cognition is scarce [102,103].

For reading comprehension, we found no effects after the physical activity intervention, but positive effects after the mindfulness intervention. These results add to heterogeneous study results after physical activity and mindfulness interventions with positive effects [69,104,105] and no effects on reading [25]. The positive effects on reading comprehension, after the mindfulness intervention, might be attributed to a better match between the intervention and the outcome variable than in the physical activity intervention. Participants in the mindfulness intervention constantly focused and processed detailed (e.g. body sensations) and abstract information (e.g. happiness, gratitude), which might tap the similar information processes as for reading comprehension [106]. The physical activity was less cognitively engaging and therefore possibly ineffective on improving comprehension, but the functionality of combined physical and cognitive interventions needed further investigation [107]. Alternatively, positive effects of mindfulness on reading comprehension could also been associated with other factors e.g., the group setting of the testing, motivational aspects, reduced mind wandering or promoted awareness due to the mindfulness interventions [54,108].

In our study, self-esteem moderated the effect between group (intervention vs. control) and gain on attention performance in study 1. Specifically, if self-esteem was high, intervention and control group did no longer differ significantly, i. e. the positive intervention effect of the physical activity group was only present in participants with low and medium self-esteem. This is in line with other study results [62] and underlines the relevance of self-esteem on learning conditions, and that self-esteem could compensate impaired attention. On the other hand, moderation was relatively small and was not present on other attention subscales in study 1, and not found accordingly on positive intervention

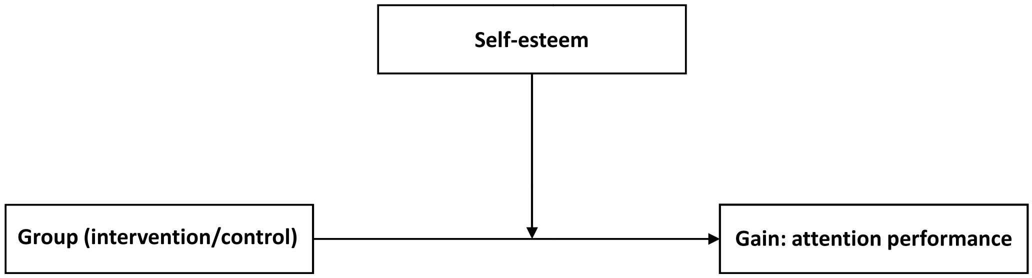

Fig 3. Study 1, Moderator model.

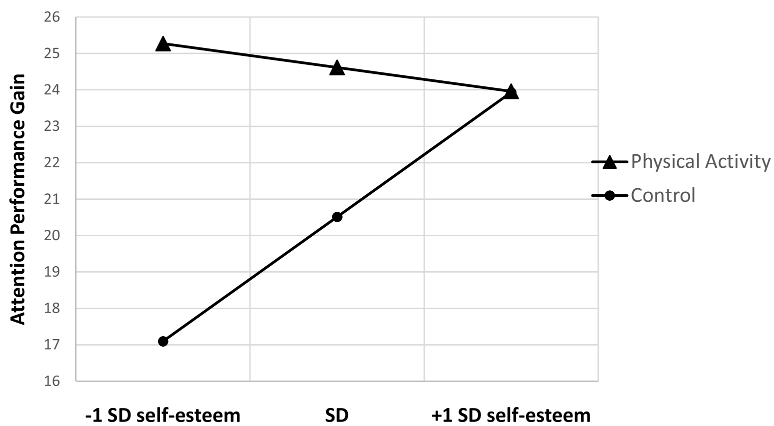

Fig 4. Regression lines showing the relationship between group (Physical activity, Control group) and attention-performance gain by "low" (-1 *SD*) to "high" (+1 *SD*) levels of self-esteem in study 1.

effects on reading comprehension in study 2.

3.1. Limitations and future research

Limitations of the present study were that samples between studies differed in size (study 1: intervention group n = 93, control group n = 69; study 2: intervention group: n = 42, control group: n = 37) and school grades (study 1: 4th grade, study 2: 5th grade). We aimed for similar conditions during interventions across studies, and that interventions were conducted simultaneously during the school year. However, access to this population was limited due competing demands of schools (keeping up regular lessons) and research (high quality studies). Another limitation was that control conditions, in study 1 and 2, differed between active and passive control groups, which impaired comparisons. Meta-analysis, which separated studies between active and passive controls, reported mixed results. Meta-analyses on mindfulness effects on children's inattentive and/or hyperactive-impulsive behavior, and meta-analyses on mindfulness on children's cognition (attention, memory, executive functions) revealed no significant difference between studies with active or passive control groups [44,109]. However, another meta-analysis on mindfulness effects on children's anxiety, found positive effects for studies with active but no effects for studies with passive controls [110]. Another limitation was that posttests of our study took place directly after the last intervention or control condition and interfered with acute and chronic effects, which should be differentiated in future studies. Additionally, in this study the reduced study time, due to the additional breaks, was not accounted although study time is essential for learning [111,112]. Even if the reduced study time was only 10-min per day, it remained undecided whether the positive intervention effects outweighed the reduced study time. Future studies should include groups with no additional breaks and include a measure for 'time on task' (e. g. [113]). We presume that breaks are an integrative part of learning, but effectiveness or point of adverse effects needed further investigation. Future studies should further explore dose-response relationships and whether specific physical activities and/or mindfulness exercises yield larger benefits for specific cognitive skills such as executive functions, different aspects, and measures of attention and other academic domains than reading. Social interactions within class should also be measured in future studies and how intervention effects might be influenced by peers and teachers. Future research should consider also individual differences (e. g. age, body mass index [114], exertion during interventions [115,116], fitness level [38] or mindfulness experience). For effect stability and long-term effects additional follow-up assessments would be necessary [117].

3.2. Underlying processes

The specific effects after the physical activity and the mindfulness practice relate to underlying processes. For physical activity, research referred to a hypothesized inverted-U relation and that cognitive performance would raise by physical-induced arousal [118] and that mindfulness interventions may benefit distribution of limited brain resources [119] or could be related to processes of the default mode network which was connected with sustained attention tasks [120]. However, further research is needed to disentangle the mechanisms involved and to test specific processes of cognitive change during recess [121].

4. Conclusion

In conclusion, classroom-based physical activity and mindfulness breaks revealed specific effects on attention and reading comprehension, which are known to support learning. Generalization of results needed to be drawn cautiously as learning and academic success depend on many more factors. Besides, classroom-based physical activities and mindfulness interventions would also have desirable side-effects on motivation as well as children's mental health.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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Compliance with Ethical Standards

Children volunteered for participation. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from the children's parents.

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